Paraxiom Harmonic Toroidal Governance Layer
(Toroidal Tonnetz Harmonic Manifold + ER-LHS)

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Abstract

We describe a harmonic, toroidal-state governance layer for AI and distributed systems. The core structure is a *Toroidal Tonnetz Harmonic Manifold* (TTHM): a discrete Tonnetz-inspired lattice of states embedded on a torus with periodic boundary conditions. On this manifold we define an *Energy–Resonance Local Harmonic Surface* (ER-LHS), a time-varying scalar field $E_i(t)$ over nodes that encodes (i) instantaneous coherence between states, (ii) temporal inertia of coherent configurations, and (iii) resonance amplification for recurrently coherent structures.

The ER-LHS induces a physically-inspired selection rule over states, weights, and node contributions. It can drive (a) model-weight fusion in federated learning, (b) validator or oracle weighting in blockchain consensus, and (c) routing and resource allocation in quantum-secure networks (e.g., QKD-backed meshes with PQC signatures). The topology is explicitly toroidal, matching typical runtime layouts (e.g., Substrate-like grids) while preserving a Tonnetz-style harmonic adjacency structure.

Contents

1 Technical Field

This invention sits at the intersection of:

- AI model-weight governance and aggregation,
- graph- and lattice-based computation on toroidal topologies,
- federated and decentralized learning over sparse distributed representations,
- blockchain and consensus—including QKD-backed and PQC-secured networks,
- harmonic and coherence-based control of distributed resources.

2 High-Level Idea

Informally:

1. Represent model states, validators, or submodules as nodes on a *Tonnetz-inspired lattice* (harmonic adjacency).
2. Embed this lattice on a *torus* by wrapping boundaries in both directions (periodic boundary conditions).
3. Define a time-varying scalar "energy" $E_i(t)$ per node that:
   - decreases with local coherence to neighbors,
   - exhibits inertia (past coherence persists),
   - is amplified by resonance (recurrent coherent patterns).
4. Use $E_i(t)$ and its derived quantities as a *governance signal*: higher weight, stake, or influence is granted to nodes in coherent, resonant regions of the harmonic torus.

This produces a state-machine-like mechanism in which:

- topology (Tonnetz + torus),
- time (inertia, resonance),
- and information content (sparse codes, gradients, measurements)

jointly determine which configurations are reinforced.

3 Toroidal Tonnetz Harmonic Manifold

3.1 Nodes and Coordinates

Let V be a finite set of nodes. Each node $i \in V$ is associated with:

- a discrete coordinate (x_i, y_i) in $\mathbb{Z}^2$,
- interpreted as a point on a Tonnetz-like harmonic lattice.

We fix lattice dimensions $L_x, L_y \in \mathbb{N}$ and impose toroidal identifications:

$$(x, y) \sim (x + L_x, y), \qquad (x, y) \sim (x, y + L_y). \tag{1}$$

Thus the manifold is a discrete torus:

$$\mathcal{M} \cong \mathbb{Z}_{L_x} \times \mathbb{Z}_{L_y}.$$

3.2 Tonnetz-style Adjacency

Classically, the Tonnetz connects pitches by harmonic intervals such as fifths and thirds. Here, we generalize this idea:

- We define a base set of *harmonic shifts*

$$\Delta = \{(\delta x_k, \delta y_k)\}_{k=1}^{K} \subset \mathbb{Z}^2,$$

  where each $(\delta x_k, \delta y_k)$ corresponds to a "harmonic interval" in our state space (not necessarily musical).
- For each node i with coordinate (x_i, y_i), its neighbors are

$$\mathcal{N}(i) = \{ j \in V \mid (x_j, y_j) \equiv (x_i + \delta x_k, y_i + \delta y_k) \pmod{(L_x, L_y)} \text{ for some } k \}.$$

Thus Tonnetz-like structure defines *which* nodes are harmonically adjacent, while the torus wraps those adjacencies without boundary.

3.3 Sparse Distributed Representations (SDRs)

Each node i holds an internal state vector $s_i(t)$, e.g., an SDR or a model-weight summary:

$$s_i(t) \in \{0, 1\}^D \quad \text{or} \quad s_i(t) \in \mathbb{R}^D.$$

We assume a similarity (or coherence) function:

$$\mathrm{sim}(s_i, s_j) \in [0, 1]$$

which can be, for example:

- Jaccard or overlap for binary SDRs,
- cosine similarity for real-valued vectors.

4 Energy–Resonance Local Harmonic Surface (ER-LHS)

4.1 Local Coherence Term

Define the instantaneous harmonic coherence of node i at time t as:

$$C_i(t) = \frac{1}{|\mathcal{N}(i)|} \sum_{j \in \mathcal{N}(i)} \mathrm{sim}\big(s_i(t), s_j(t)\big). \tag{2}$$

$C_i(t)$ is high when i is well-aligned with its Tonnetz neighbors on the torus.

4.2 Inertia (Temporal Coherence Memory)

We introduce a scalar "inertia" state $I_i(t)$ per node:

$$I_i(t+1) = \alpha\, I_i(t) + (1 - \alpha)\, C_i(t), \qquad \alpha \in [0, 1). \tag{3}$$

Interpretation:

- For α near 0, inertia is short-lived; $I_i(t)$ tracks current coherence closely.
- For α near 1, inertia is long-lived; $I_i(t)$ retains a history of past coherence.

4.3 Resonance Amplification

Define a resonance variable $R_i(t)$ to capture the degree to which node i has been *recurrently* coherent:

$$R_i(t+1) = \beta\, R_i(t) + \gamma\, [I_i(t) \cdot C_i(t)], \qquad \beta \in [0, 1),\ \gamma > 0. \tag{4}$$

Here:

- $I_i(t) \cdot C_i(t)$ is large when current coherence is high and inertia is already high—a basic multiplicative resonance.
- β controls decay; γ controls gain.

4.4 Energy Definition

The ER-LHS associates to each node i a scalar "energy" $E_i(t)$:

$$E_i(t) = w_c(1 - C_i(t)) + w_I(1 - I_i(t)) - w_R R_i(t) + \varepsilon_i(t), \tag{5}$$

with nonnegative weights w_c, w_I, w_R and a small noise or exploration term $\varepsilon_i(t)$.

Interpretation:

- High coherence C_i and inertia I_i *lower* energy.
- High resonance R_i strongly *lowers* energy.
- Spurious or misaligned nodes have higher energy.

The ER-LHS at time t is the collection:

$$\mathcal{E}(t) = \{E_i(t)\}_{i \in V}.$$

5 Selection and Governance Dynamics

5.1 Local Minimization

At a given time t, one may define a local selection rule such as:

$$i^*(t) = \arg\min_{i \in V} E_i(t), \tag{6}$$

or, more generally, a Gibbs-style distribution:

$$\pi_i(t) = \frac{\exp(-\lambda E_i(t))}{\sum_{j \in V} \exp(-\lambda E_j(t))}, \qquad \lambda > 0. \tag{7}$$

$\pi_i(t)$ can then be used as:

- a weighting for model fusion,
- a voting weight or stake multiplier in consensus,
- a routing preference in a network.

5.2 Federated / Decentralized Learning

Suppose each node i holds a local model with parameters $\theta_i(t)$ and produces a gradient-like update $g_i(t)$ or a full candidate parameter vector $\hat{\theta}_i(t)$.

A global or regional aggregator can compute $\pi_i(t)$ and then:

$$\theta_{\text{global}}(t+1) = \sum_{i \in V} \pi_i(t)\, \hat{\theta}_i(t), \tag{8}$$

or, for gradients,

$$\theta(t+1) = \theta(t) - \eta \sum_{i \in V} \pi_i(t)\, g_i(t). \tag{9}$$

Nodes that remain consistently coherent (high C_i), whose coherence persists (high I_i), and that resonate with repeated patterns (high R_i) gain *persistent influence* via the harmonic torus.

5.3 Consensus and Validator Weighting

In a blockchain or distributed ledger:

- Nodes are validators or oracle operators.
- Their states $s_i(t)$ summarize observed blocks, QKD channel statistics, PQC signature behavior, or their past consistency.

The ER-LHS framework can be used to:

1. Penalize nodes with low harmonic coherence to neighbors (e.g., outlier behavior not supported by adjacent nodes).
2. Reward nodes embedded in resonant, stable regions of the torus.
3. Modulate stake-based or VRF-based leader selection by $\pi_i(t)$.

6 Quantum-Secure Integration (QKD, PQC)

The framework is agnostic to the underlying transport, but can be specialized to quantum-secure settings:

- QKD links provide per-edge metrics such as quantum bit error rate (QBER), sifted key rate, or entanglement quality.
- These metrics can be embedded into $s_i(t)$ or directly into the coherence function.

For example, for neighboring nodes i, j:

$$\mathrm{sim}(s_i, s_j) = \phi(\mathrm{QBER}_{ij}(t), \mathrm{key\_rate}_{ij}(t), \dots), \tag{10}$$

for some monotone map ϕ producing $[0,1]$-valued coherence.

Nodes that sit on stable, low-QBER, high-quality quantum paths will naturally occupy low-energy, resonant basins of the ER-LHS, gaining governance weight.

PQC elements (e.g., SPHINCS+, ML-DSA, etc.) can contribute:

- signature failure rates,
- verification latencies,
- key-rotation coherence across neighbors.

These are also foldable into $s_i(t)$ and sim.

7 TikZ Illustrations

7.1 Tonnetz Patch on the Torus

Figure 1 sketches a small Tonnetz-like patch with toroidal identification.

7.2 Energy Surface Concept

Figure 2 is a conceptual sketch indicating low-energy (coherent, resonant) basins on the torus.

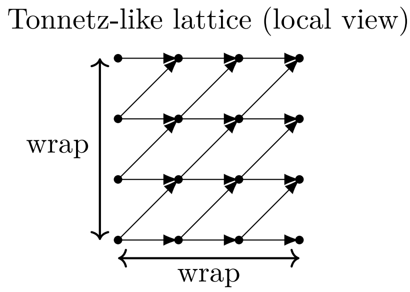

Figure 1: Tonnetz-inspired lattice patch with periodic wrap (toroidal).

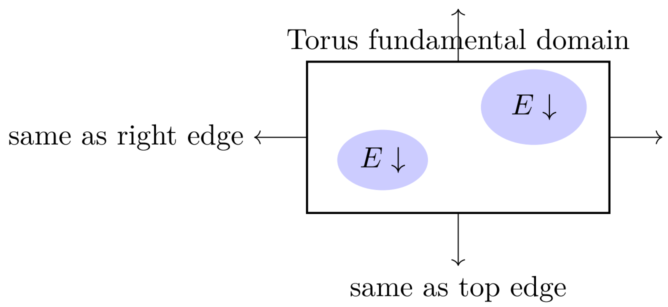

Figure 2: Conceptual ER-LHS energy basins on a toroidal domain.

8 Implementation Notes

8.1 Runtime Layout

The toroidal Tonnetz manifold maps cleanly onto:

- multi-core grids,
- Substrate-like node indexation (validators on a ring / grid),
- GPU blocks or FPGA logical tiles.

Each *Paraxiom harmonic cell* can be:

- a node in a blockchain,
- a shard in a federated model,
- a quantum repeater or QKD endpoint.

8.2 Update Loop (Sketch)

For each time step t:

1. Acquire new states $s_i(t)$ from each node.
2. Compute $C_i(t)$ via Eq. (2).
3. Update inertia $I_i(t+1)$ by Eq. (3).
4. Update resonance $R_i(t+1)$ by Eq. (4).
5. Compute energy $E_i(t+1)$ via Eq. (5).
6. Derive weights $\pi_i(t+1)$ via Eq. (7).
7. Apply $\pi_i(t+1)$ to:
    - fuse models, or
    - weight votes / blocks, or
    - bias routing / scheduling.

9 Claims (Informal Draft)

C1. A method for governing contributions of distributed nodes in a computer system, comprising:

(a) arranging the nodes on a discrete toroidal lattice with Tonnetz-inspired harmonic adjacency;
(b) associating with each node a state vector and computing local coherence to harmonic neighbors;
(c) maintaining, for each node, temporal inertia and resonance variables based on repeated coherence;
(d) defining an energy value per node as a function of coherence, inertia, and resonance (ER-LHS);
(e) assigning node weights based on the energy values and using said weights to control at least one of: model aggregation, consensus, routing, or resource allocation.

C2. The method of Claim **C1**, wherein the toroidal lattice is used to match a runtime grid or validator indexation, such that harmonic adjacency corresponds to physical, logical, or organizational locality.

C3. The method of any of the preceding claims, wherein the state vectors represent sparse distributed representations and the coherence function is an overlap measure on said representations.

C4. The method of any of the preceding claims, wherein the nodes are part of a quantum-secure network and the coherence function incorporates QKD channel metrics and/or PQC signature behavior.

C5. A non-transitory computer-readable medium storing instructions which, when executed by one or more processors, implement the method of any of Claims **C1**–**C4**.

10 Non-Claims

This defensive publication does not claim:

- Optimality of the toroidal topology over other manifold structures
- Biological realism or neural plausibility of the harmonic model
- Completeness of the governance mechanism for all distributed system scenarios
- Novelty of individual components (Tonnetz, torus, Hamiltonian dynamics) in isolation

The novelty lies in the specific combination and application of these elements to distributed governance, particularly the ER-LHS energy functional operating on a toroidal Tonnetz manifold for coherence-based selection.

11 Conclusion

The Paraxiom Harmonic Toroidal Governance Layer defines a concrete mechanism for embedding model states, validators, or agents on a toroidal Tonnetz manifold and evolving an energy landscape (ER-LHS) over that manifold via coherence, inertia, and resonance. This provides a physically-inspired, topology-aware layer of governance applicable to AI, quantum-secure networks, and decentralized infrastructure.